

allocated frequency band while enabling the use of the signals for precise metrology.

The acquisition signals (unmodulated tones) do extra duty by making it possible to increase the precision of range and bearing measurements: The ranging code used in Ultra-BOC is adequate to resolve the ambiguity of a synthesized delay formed by a pair of closely-spaced unmodulated BOC tones. This delay is used to resolve the ambiguity on a more

widely spaced pair of tones. This process is continued with increasingly widely spaced tones until either the range and bearing precision requirements are satisfied by use of such pairs of tones or the integer-cycle ambiguities in the phases of the carrier signals are resolved. The range measurements made in this manner can be more precise than are those that can be made by use of the PRN codes alone, because (1) the delays synthesized from pairs of tones have smaller

errors attributable to system noise and (2) multipath-induced errors are the leading errors in ranging by use of PRN and the delays synthesized from pairs of tones are less susceptible to multipath-induced errors.

*This work was done by Lawrence Young, Jeffrey Tien, and Jeffrey Srinivasan of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).  
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## Automated Analysis, Classification, and Display of Waveforms

**Trends in operation of systems that generate waveforms can be spotted in real time.**

*John F. Kennedy Space Center, Florida*

A computer program partly automates the analysis, classification, and display of waveforms represented by digital samples. In the original application for which the program was developed, the raw waveform data to be analyzed by the program are acquired from space-shuttle auxiliary power units (APUs) at a sampling rate of 100 Hz. The program could also be modified for application to other waveforms — for example, electrocardiograms.

Before this program became available, the raw APU waveforms were recorded on paper strip charts — a practice that imposed a substantial workload on human operators and was not conducive to consistently accurate, real-time analysis and classification. The program reduces the operator workload, increases the accuracy of classifications, and presents results in real time.

The program begins by performing principal-component analysis (PCA) of 50 normal-mode APU waveforms. Each waveform is segmented. A covariance matrix is formed by use of the seg-

mented waveforms. Three eigenvectors corresponding to three principal components are calculated. To generate features, each waveform is then projected onto the eigenvectors. These features are displayed on a three-dimensional diagram, facilitating the visualization of the trend of APU operations.

It is necessary to classify each of the normal-mode waveforms as being characteristic of one of three mode types known among APU specialists as “nominal,” “engine,” or “aero.” For this purpose, each waveform is segmented and its average energy is computed. For engine and aero modes, time information is also used, and information about peaks in the waveforms is used to determine which mode is present.

It is also necessary, when there is a malfunction, to classify waveforms as being characteristic of one or more error mode(s). To enable such classification of a waveform in real time, it is necessary to prepare the software and associated data base in a prior process that includes a careful analysis of the wave-

form known to be associated with each of at least five known error modes to which the APUs are subject. For each error mode, some distinct features of the waveform are extracted. Thereafter, in operation, a waveform is automatically classified as belonging to an error mode according to a few rules based on these features.

*This program was written by Chiman Kwan, Roger Xu, David Mayhew, and Frank Zhang of Intelligent Automation, Inc., and Alan Zide and Jeff Bonggren of the Boeing Co. for Kennedy Space Center.*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:*

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*Refer to KSC-12568, volume and number of this NASA Tech Briefs issue, and the page number.*

## Fast-Acquisition/Weak-Signal-Tracking GPS Receiver for HEO

*Goddard Space Flight Center, Greenbelt, Maryland*

A report discusses the technical background and design of the Navigator Global Positioning System (GPS) receiver — a radiation-hardened receiver intended for use aboard spacecraft. Navigator is capable of weak signal acquisition and tracking as well as much faster acquisition of strong or weak signals with no *a priori* knowledge or external

aiding. Weak-signal acquisition and tracking enables GPS use in high Earth orbits (HEO), and fast acquisition allows for the receiver to remain without power until needed in any orbit. Signal acquisition and signal tracking are, respectively, the processes of finding and demodulating a signal. Acquisition is the more computationally difficult

process. Previous GPS receivers employ the method of sequentially searching the two-dimensional signal parameter space (code phase and Doppler). Navigator exploits properties of the Fourier transform in a massively parallel search for the GPS signal. This method results in far faster acquisition times [in the lab, 12 GPS satellites have been ac-